Development of a High Refractive Index Aerogel Cherenkov Detector for the Spectroscopy of η' Mesic Nuclei

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We have developed a Cherenkov counter using a high-refractive-index aerogel [1] for the hardware particle identification in the spectroscopy experiment of η' mesic nuclei with the (p,d) reaction [2, 3, 4]. In this experiment, we employ a 2.5 GeV proton beam of SIS-18 or SIS-100. Using the (Super-) FRS as a spectrometer, we measure the missing masses of the (p,d) reaction on ^{12}C target by momentum-measurement of ejectile deuterons. The expected rates at the focal planes are 0.5 kHz for the signal deuteron and 50 kHz for the background protons. Thus, we decided to develop a Cherenkov counter to provide hardware background rejection at a level of 1/500 based on the velocity difference of the signal (0.82 – 0.85) and the background (0.94 – 0.96) particles.

The structure of the developed detector is shown in Fig.1. As a radiator, we used a 2 cm-thick silica aerogel with a refractive index of 1.18 [5]. In the back of the radiator, a box consisting of mirror planes was placed to guide the Cherenkov photons to the eight PMTs attached to this box.

In November 2012, we have conducted a performance test of this detector using deuteron beams at GSI. We simulated the signals and backgrounds in our main experiment by using deuteron beams at two velocities $\beta = 0.843$ and 0.944, respectively.

We observed a sufficient number of photoelectrons to provide an anti-coincidence with the higher-velocity deuterons (background-like). The solid line in Fig.2 is the histogram of the total number of photoelectrons for this velocity. Analyzing the histogram, we obtain the mean number of photoelectrons to be 30.8, which gives an efficiency higher than 99.9 % setting the threshold at 9 photoelectrons. This is quite sufficient for the background rejection in the main experiment.

The observed histogram with the lower-velocity deuterons (signal-like) is shown by the dashed line in Fig.2. Although a peak was seen at the pedestal position, as expected, also a long tail up to more than 10 photoelectrons was observed. This can be caused by Cherenkov radiation in the ultraviolet region and/or Cherenkov photons emitted by delta rays produced in the aerogel. This tail will lead to a few percent overkill of the signal deuterons (e.g., 3 % at a 9-photoelectron threshold) in the main experiment.

The test experiment demonstrated that this Cherenkov detector can be used for the hardware background rejection in the spectroscopy experiment of η' mesic nuclei. As a near-future work, we will consider a possible improvement to reduce the expected signal overkill by testing a lower-refractive index radiator.

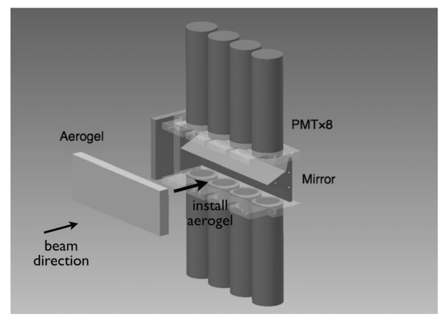

Figure 1: The structure of the aerogel Cherenkov detector. The radiator can be installed from the upstream side.

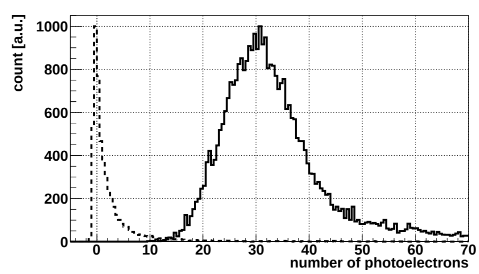

Figure 2: Histograms of the total number of photoelectrons. The solid line is for the higher velocity, $\beta = 0.944$. The dashed line is for the lower velocity, $\beta = 0.843$.

References

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